National Academies DS perspective ---

A perspective from a member of the NAS Decadal Survey and the Decadal Midterm Review Committees
(*and a committed topoholic*)

William E. Dietrich
UC Berkeley

November 14, 2023

Brief summary of the Decadal Survey recommendations

Status of the execution of the Decadal Survey by NASA

The Midterm Committee Tasks

STV incubation program comments

Public presentation by Waleed Abdalati presented to the Midterm Committee Sept. 28, 2023

COMMITTEE ON THE DECADAL SURVEY FOR EARTH SCIENCE AND APPLICATIONS FROM SPACE

WALEED ABDALATI, University of Colorado, Boulder, *Co-Chair*
WILLIAM B. GAIL, Global Weather Corporation, *Co-Chair*
ANTONIO J. BUSALACCHI, JR., NAE,[1] University Corporation for Atmospheric Research, *Co-Chair*[2] STEVEN J. BATTEL, NAE, Battel Engineering, Inc.
STACEY W. BOLAND, Jet Propulsion Laboratory
ROBERT D. BRAUN, NAE, University of Colorado
SHUYI S. CHEN, University of Washington
WILLIAM E. DIETRICH, NAS,[3] University of California, Berkeley
SCOTT C. DONEY, University of Virginia
CHRISTOPHER B. FIELD, NAS, Stanford University
HELEN A. FRICKER, Scripps Institution of Oceanography
SARAH T. GILLE, Scripps Institution of Oceanography
DENNIS L. HARTMANN, NAS, University of Washington
DANIEL J. JACOB, Harvard University
ANTHONY C. JANETOS, Boston University
EVERETTE JOSEPH, University of Albany, State University of New York
MOLLY K. MACAULEY,[4] Resources for the Future
JOYCE E. PENNER, University of Michigan
SOROOSH SOROOSHIAN, NAE, University of California, Irvine
GRAEME L. STEPHENS, NAE, Jet Propulsion Laboratory, California Institute of Technology
BYRON D. TAPLEY, NAE, University of Texas, Austin
W. STANLEY WILSON, National Oceanic and Atmospheric Administration (retired)

What We Were Asked to Do

OVERARCHING TASKS

- Assess **progress from 2007**
- Develop a prioritized list of top-level **science and application objectives** for 2017-2027
- Identify gaps and opportunities in the **programs of record** at NASA, NOAA, and USGS
- Recommend approaches to facilitate the development of a robust, resilient, and appropriately balanced U.S. **program of Earth observations** from space

GENERAL & AGENCY-SPECIFIC TASKS

- **Cross-Agency**
  - Enabling activities
  - Partnerships & synergies
- **NASA**
  - Program balance and scope
  - Ventures flight element
  - Decision principles and measurement continuity
- **NOAA and USGS**
  - Non-traditional observation sources
  - On-ramp of scientific advances
  - Research-to-operations
  - Technology replacement/infusion

Quick Summary: Recommendations

1

VISION & STRATEGY

"Thriving on our Changing Planet"

2

SCIENCE & APPLICATIONS

Address **35 key science/applications questions,** from among hundreds suggested. Those with objectives prioritized as most important fell into **six categories**:

- Coupling of the Water and Energy Cycles
- Ecosystem Change
- Extending & Improving Weather and Air Quality Forecasts
- Sea Level Rise
- Reducing Climate Uncertainty & Informing Societal Response
- Surface Dynamics, Geological Hazards and Disasters

3

OBSERVATIONS

Augment the **Program of Record** with **eight priority observables**:

- **Five** that are specified to be implemented:
  - *Aerosols*
  - *Clouds, Convection, & Precipitation*
  - *Mass Change*
  - *Surface Biology & Geology*
  - *Surface Deformation & Change*
- **Three** others to be selected competitively from among seven candidates
- Structure **new NASA mission program elements** to accomplish this
- Methods for new NASA capabilities to be **leveraged by NOAA and USGS**

4

PROGRAMMATICS

- CROSS-AGENCY
- NASA
  - Flight
  - Technology
  - Applications
- NOAA
- USGS

Recommended NASA Flight Program Elements

Program of Record.
The series of existing or previously planned observations, which **should be completed as planned**. Execution of the ESAS 2017 recommendation requires that the total cost to NASA of the Program of Record *flight missions from FY18-FY27 be capped at $3.6B.*

- ***Designated.*** A new program element for ESAS-designated cost-capped medium- and large-size missions to address ***observables essential to the overall program*** and that are outside the scope of other opportunities in many cases. Can be competed, at NASA discretion.
- ***Earth System Explorer.*** A new program element involving competitive opportunities for medium-size instruments and missions serving specified ESAS-priority observations. ***Promotes competition among priorities.***
- ***Incubation.*** A new program element, focused on investment for priority observation opportunities needing advancement prior to cost-effective implementation, including an Innovation Fund to respond to emerging needs. ***Investment in innovation for the future***.
- ***Venture.*** Earth Venture program element, as recommended in ESAS 2007 with the addition of a new Venture-Continuity component to provide ***opportunity for low-cost sustained observations***.

Recommended NASA Priorities: Designated

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Aerosols	**Aerosol properties, aerosol vertical profiles, and cloud properties** to understand their direct and indirect effects on climate and air quality	Backscatter lidar and multi-channel/multi-angle/polarization imaging radiometer flown together on the same platform	X		
Clouds, Convection, & Precipitation	**Coupled cloud-precipitation state and dynamics** for monitoring global hydrological cycle and understanding contributing processes	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	X		
Mass Change	**Large-scale Earth dynamics** measured by the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology & Geology	**Earth surface geology and biology,** ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR	X		
Surface Deformation & Change	**Earth surface dynamics** from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	X		

Recommended NASA Priorities: Explorer

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Greenhouse Gases	**CO_2 and methane fluxes and trends,** global and regional with quantification of point sources and identification of source types	Multispectral short wave IR and thermal IR sounders; or lidar**		X	
Ice Elevation	**Global ice characterization** including elevation change of land ice to assess sea level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar**		X	
Ocean Surface Winds & Currents	**Coincident high-accuracy currents and vector winds** to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift.	Radar scatterometer		X	
Ozone & Trace Gases	**Vertical profiles of ozone and trace gases** (including water vapor, CO, NO_2, methane, and N_2O) globally and with high spatial resolution	UV/IR/microwave limb/nadir sounding and UV/IR solar/stellar occultation		X	
Snow Depth & Snow Water Equivalent	**Snow depth and snow water equivalent** including high spatial resolution in mountain areas	Radar (Ka/Ku band) altimeter; or lidar**		X	
Terrestrial Ecosystem Structure	**3D structure of terrestrial ecosystem** including forest canopy and above ground biomass and changes in above ground carbon stock from processes such as deforestation & forest degradation	Lidar**		X	
Atmospheric Winds	**3D winds in troposphere/PBL** for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		X	X

Recommended NASA Priorities: Incubation/Other

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Atmospheric Winds	**3D winds in troposphere/PBL** for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		X	X
Planetary Boundary Layer	**Diurnal 3D PBL thermodynamic properties and 2D PBL structure** to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights.	Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar** for PBL height			X
Surface Topography & Vegetation	**High-resolution global topography** including bare surface land topography ice topography, vegetation structure, and shallow water bathymetry	Radar; or lidar**			X
** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables					

Other ESAS 2017 Targeted Observables, not Allocated to a Flight Program Element	
Aquatic Biogeochemistry	**Radiance Intercalibration**
Magnetic Field Changes	**Sea Surface Salinity**
Ocean Ecosystem Structure	**Soil Moisture**

Innovation

- Tension between ensuring the achievement of critical objectives, and innovation in the program – all within a short decade
- Innovation achieved programmatically through the ***Earth System Explorer*** element
  - Allows pressure of competition to promote innovative approaches to achieving science objectives
- Infusion of resources into ***Incubation*** element for developing needed capabilities for beyond the next decade
- Opportunity to innovate in ***Earth Venture***, in particular ***Venture-Continuity***

The recommended sustained Incubation program will make possible development of capabilities that are difficult to achieve through one-off competitive calls, something long sought by managers of Earth observation programs at NASA, NOAA, and the USGS.

Programmatics - NASA

Rec 4.6 Apply **decision rules** (included) to maintain programmatic balance (programmatic balance was a high priority)

Rec 4.7 Small scope changes to **applications & technology programs**

Rec 4.8 Reevaluate **Ventures structure** at mid-term

Rec 3.3 **Avoiding cost growth** is critical to program's success (capability and reliability are where the flexibility must be found)

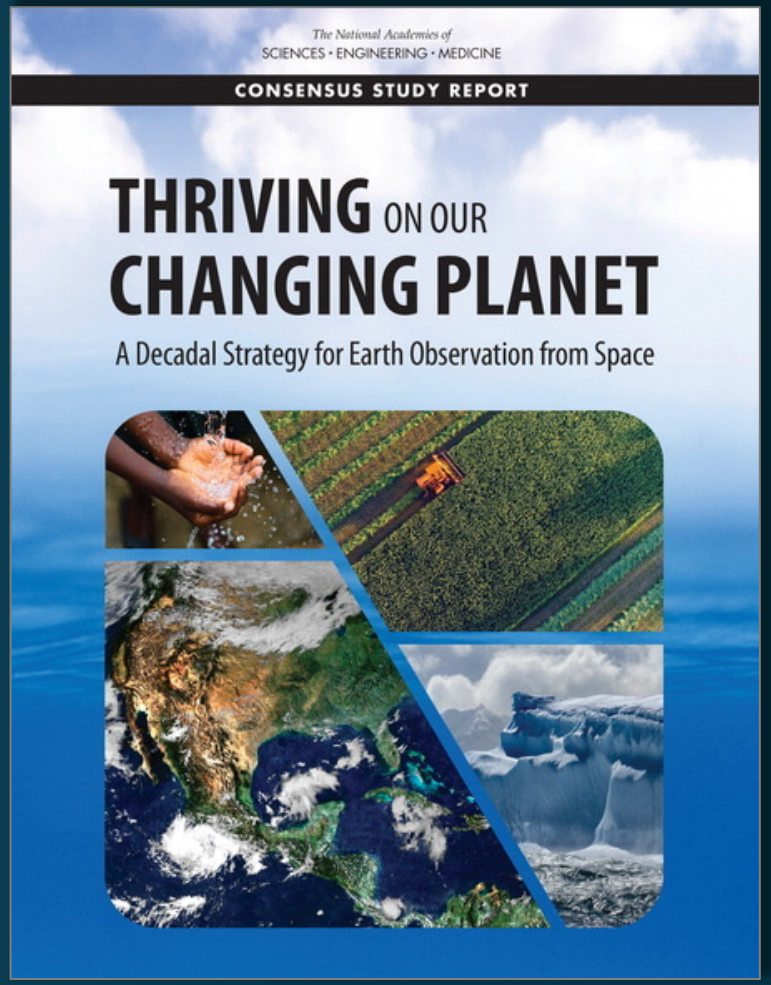
For each **Targeted Observable in the Incubation program element**, a *coordinated program* of strategic investments in technology, research, modeling, or data system development would be developed by NASA toward maturing the overall measurement concepts.

NASA Earth Science at the Decadal Midterm:

Progress and Opportunity

NASA Earth Science Division's Decadal Strategy:

- Meet our Program of Record commitments to advance flight, research, applications and technology
- Implement next-generation capability to meet the Designated Observables and Explorers
- Position NASA Earth Science to maximize science and societal benefit



Decadal Survey Incubation Program: Accomplishments

Maturation of instrument technology, measurements, and mission concepts to address high-priority Planetary Boundary Layer (PBL) and Surface Topography and Vegetation (STV) science (for 2027-2037)

- **ROSES-19 Solicitation** resulted in PBL and STV study teams and foundational study papers
- **ROSES-21 Solicitation** 35 selections awarded in FY22
  - science; technology development; OSSE's
  - PBL/STV Incubation Team (IT) science/technology co-leads
- DSI leverages relevant awards in IIP, AIST, ACT, and FINESST
- **PBL field campaign – CPEX-CV** (Cabo Verde) Sept 2022
- **STV field campaign – AfriSAR-2** (Ghana, Nigeria, Gabon, Sao Tome, DRC, Tanzania, and Mozambique) Q4 2023 – Q2 2024
- **Upcoming activities**
  - PBL Community Meeting, Washington, DC, Oct. 2-3, 2023
  - STV Community Meeting, Pasadena, CA, Nov. 14-15, 2023
  - The next DSI solicitation is expected in Q3 FY24

DSI-21 Selection Distribution	PBL	STV
Science	12	13
OSSE	1	2
Technology	3	3
IT Co-Lead	1	-
Totals	**17**	**18**

https://esto.nasa.gov/incubation/

EARTH SYSTEM OBSERVATORY

INTERCONNECTED CORE MISSIONS

$3.5B total investment for first four ESO missions

AOS-Storm and AOS-Sky

CLOUDS, CONVECTION AND PRECIPITATION

Water and Energy in the Atmosphere

AEROSOLS

Particles in the Atmosphere

SURFACE BIOLOGY AND GEOLOGY

Earth Surface & Ecosystems

SURFACE DEFORMATION AND CHANGE

Earth Surface Dynamics

Met by NISAR launch in 2024

MASS CHANGE

Large-scale Mass Redistribution

Designated Observables now in Mission Formulation

ESO Core Missions

- Successfully completed Mission Concept Reviews Summer 2022
- Missions passed KDP-A and now in Formulation
- ESO Independent Review Board, July-October 2022
  - IRB report and NASA response posted at nasa.gov/reports
- AOS-Storm and AOS-Sky have Phase A trade studies under way
- SDC will remain in extended study phase to take advantage of NISAR mission

AOS-Storm AOS-Sky	**SBG**	**GRACE-C**	**SDC**
MCR: May 2022 KPD-A: Jan 2023	MCR: June 2022 KDP-A: Nov 2022	MCR: Jun 2022 KDP-B: Sept 2023	Remaining in Extended Study Phase

MCR – Mission Concept Review

KDP – Key Decision Points

AOS- Atmosphere Observing System SBG- Surface Biology and Geology GRACE-D = Mass Change SDC- Surface Deformation and Change

Earth System Explorers (ESE)

EARTH SYSTEM OBSERVATORY

- Final Announcement of Opportunity (AO) released on May 2, 2023
- AO closed August 2, 2023
- Step 1 selection anticipated Q3 FY24
- PI-Managed Mission Cost (PIMMC) cap of $310M (FY24 $)
- NASA will provide launch vehicle services
- Two-step selection process

- New Earth System Explorers Program Office established at GSFC; SRR/SDR completed in March 2023 and KDP-I in June 2023

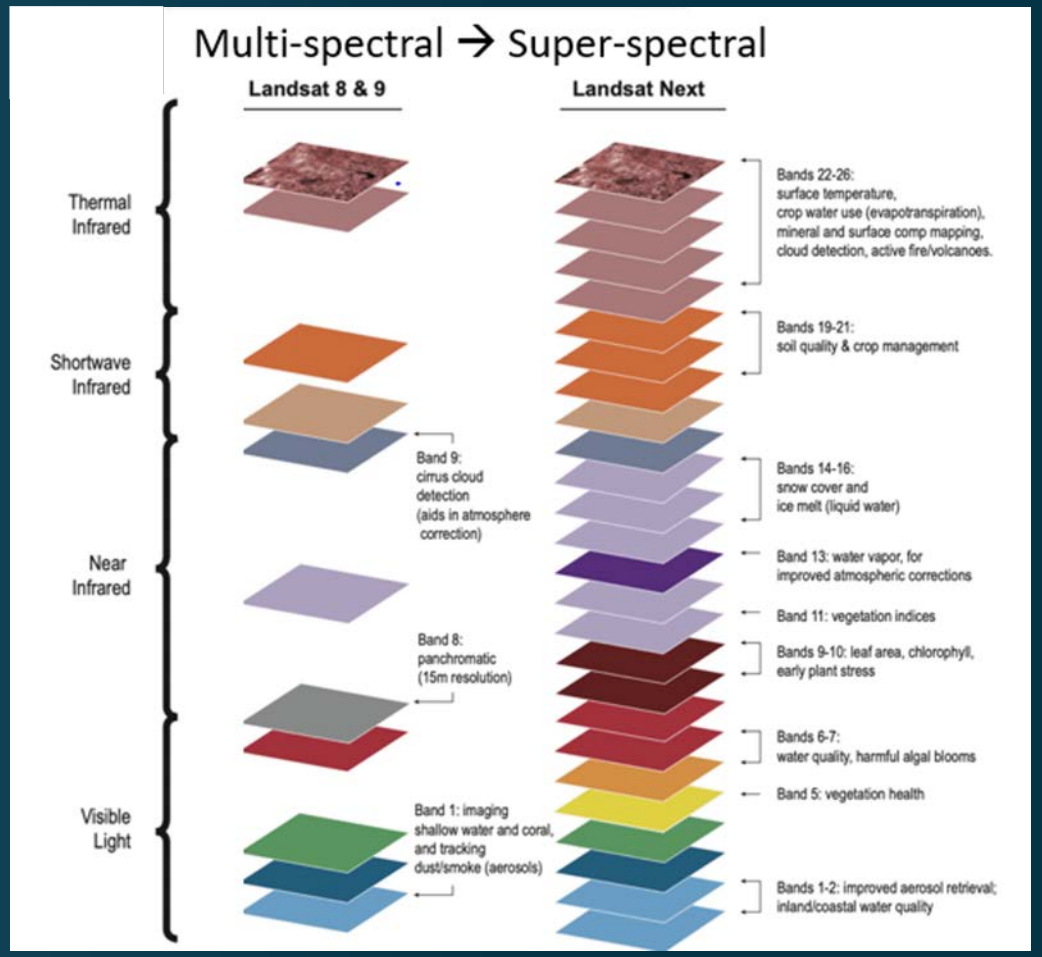
Landsat Next

Landsat Next mission is a constellation of three identical satellites, approximately equally distributed in orbit

- ≤ 9 day global land revisit frequency
- 26 spectral bands (21 VSWIR; 5 TIR)
- Target Launch Readiness Date: November 2030

Status and next steps:

- Held KDP-A Program Management Council on Nov. 2
- Landsat Instrument Suite proposals currently under evaluation with award planned in spring of 2024.



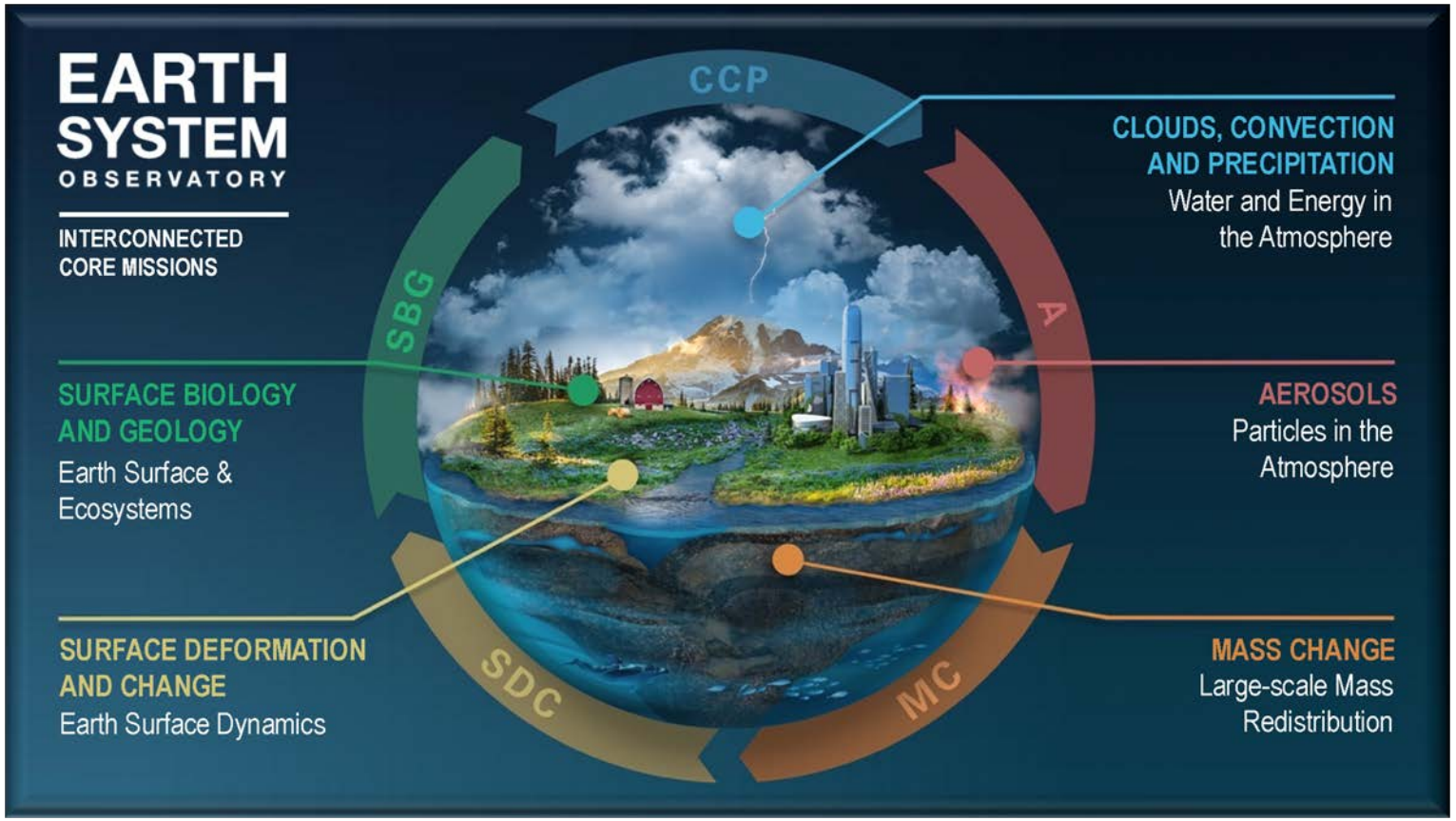
Landsat Next will provide more than twice as many spectral bands, with resolution improved by a factor of 2, and with the repeat coverage of Landsats 8 and 9, *combined*

Earth System Observatory (ESO) Independent Review Board (IRB) Final Report

https://www.nasa.gov/wpcontent/uploads/2022/11/eso_irb_documents.pdf

Summary Presentation to ESAS 2017 Midterm review Committee *(Subset of the Final IRB Report)*

September 27, 2023



NASA Budget Compliance

Designated
Two <$800 million FY2018
One <$650 million
One <$500 million
One <$300 million

Explorer
Three <$350 million

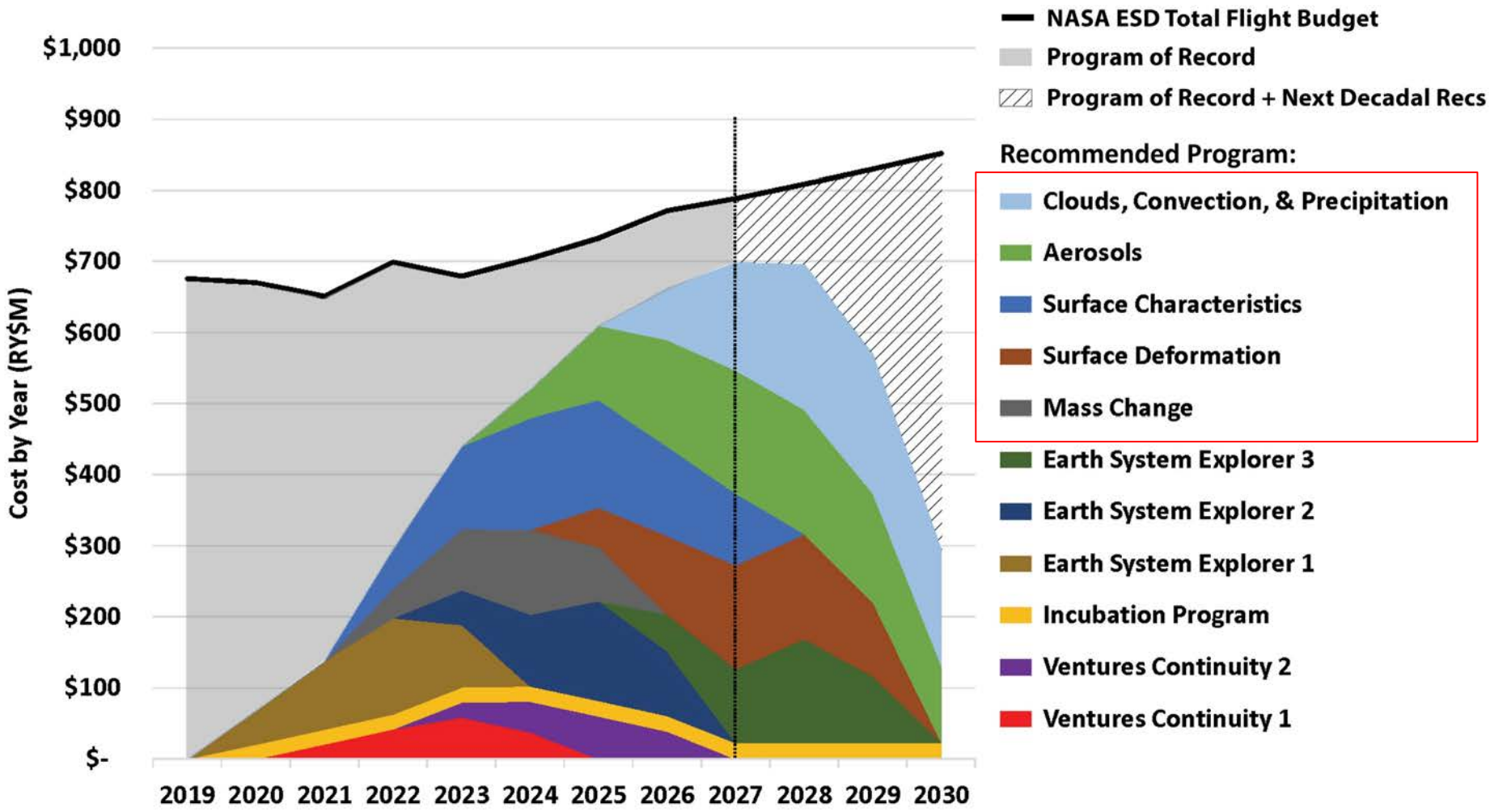
Venture- Continuity
Two <$150 million

Incubation
$20 million/year

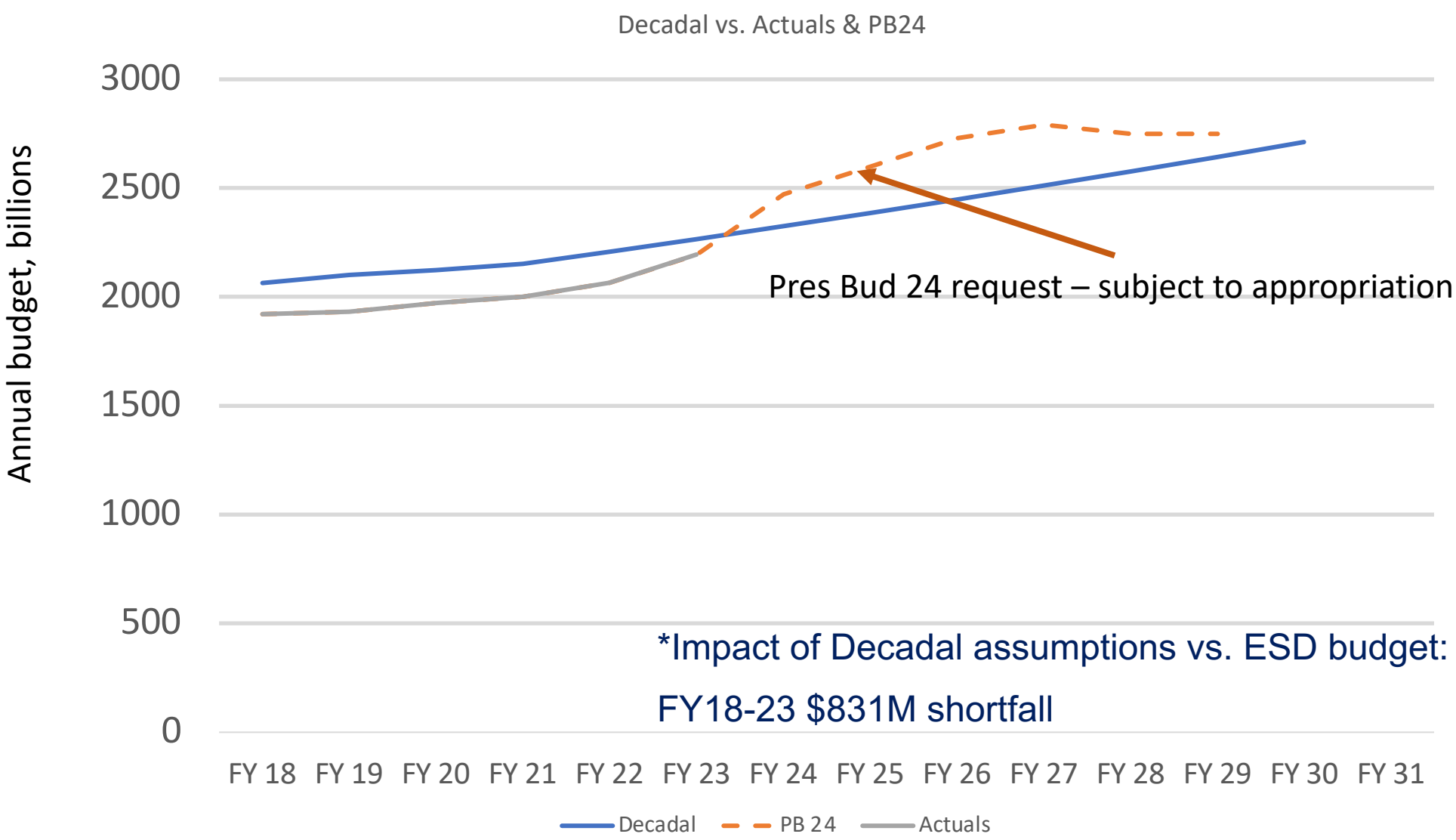
All costs exceeded

Missions delayed

Mission numbers reduced

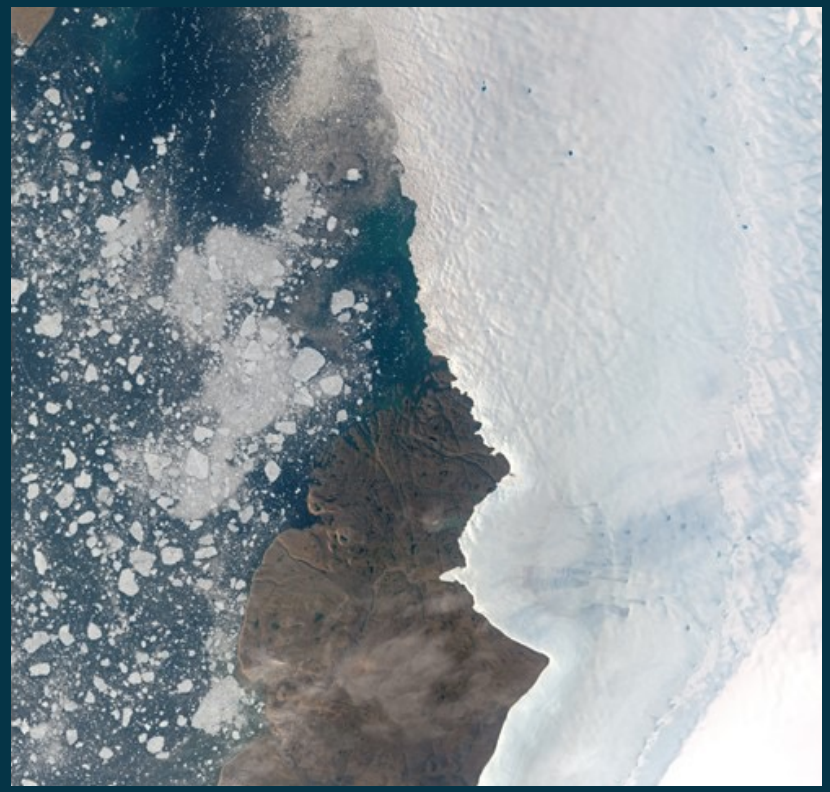


- Liens from last decade into this one are substantial
- Very little flexibility to absorb funding challenges until mid decade
- Committee sought to keep liens lower on next decade
  - Allows more flexibility for next decadal survey
  - Some carry over of programs into subsequent decade is required


Decadal vs. Actuals & PB24
Annual budget, billions
3000
2500
2000
1500
1000
500
0
FY 18
FY 19
FY 20
FY 21
FY 22
FY 23
FY 24
FY 25
FY 26
FY 27
FY 28
FY 29
FY 30
FY 31
Pres Bud 24 request – subject to appropriation
*Impact of Decadal assumptions vs. ESD budget:
FY18-23 $831M shortfall
Decadal
PB 24
Actuals

Accumulating Budget Challenges: Reduced Buying Power

Factor	Impact (approx.)
DS Budget growth assumptions	$1.74B
DS Landsat Next Budget assumptions	$450M
COVID-19	$300M
Tech challenges	$250M
Cost estimate optimism & record inflation	$500M
Total impact	**$3.2B**



Melting on Humboldt Glacier *NASA Earth Observatory images by Wanmei Liang, using Landsat data from the U.S. Geological Survey.*

Midterm Review of the 2017 Decadal Survey

7 Tasks assigned to committee, including…

Assess the degree to which the programs of NASA, NOAA and the USGS address the strategies, goals, and priorities outlined in the 2017 decadal survey…

Recommend actions that could be taken to optimize the full breadth of NASA's Earth science programs during the remaining decadal interval.

Recommend any actions that NASA, NOAA and the USGS should undertake to prepare for the next decadal survey, including information, observables, pathfinders, or technology.

Co-Chairs Christian D. Kummerow and Anna M. Michalak

Members
Stacey W. Boland
Francisco P. Chavez
William E. Dietrich
Deanna Hence
Daniel J. Jacob
Dennis P. Lettenmaier
Kathleen (Kass) O'Neill Green
Lesley E. Ott
David T. Sandwell
Susan L. Ustin
Isabella Velicogna
Xubin Zeng

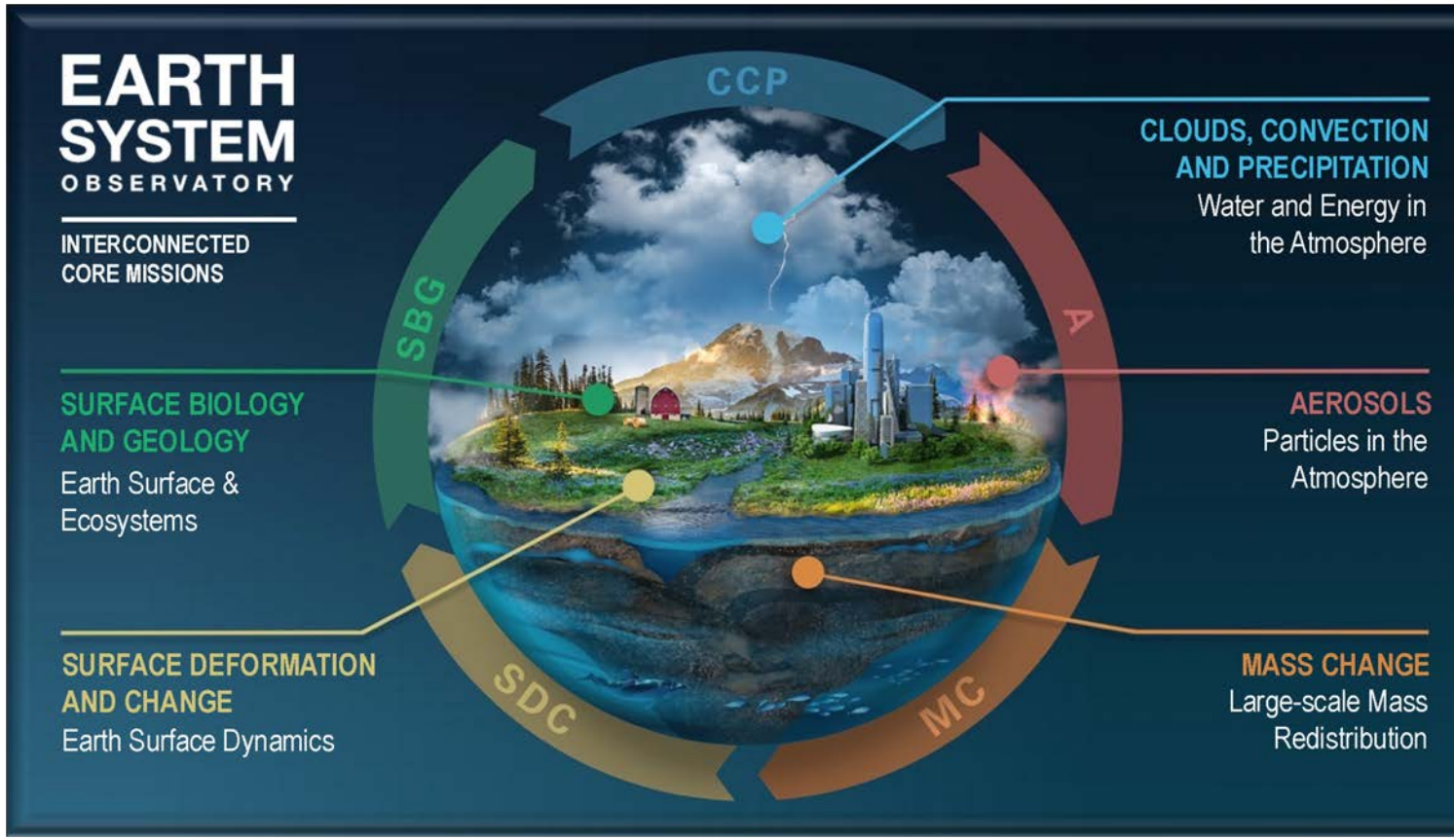
https://drive.google.com/drive/folders/1ttHvpxP5wzq_QL8-1dn77ouz-weuopgU?usp=drive_link

https://vimeo.com/event/3731315

Staff Officers Arthur A. Charo, Dwayne A. Day and Tarini Konchady

General issues mentioned in public presentations to the Midterm Review Committee

1. **Budget**
2. **Continuity** (MC+ Landsat Next)
3. **Innovation (Incubation, Explorer, Venture)**
4. **International partners**
5. **Commercial resources**



As already mentioned, the budget was stressed by unanticipated costs. This is partly responsible for the delay in launch schedule and increased mission costs:

Aersols (AOS Sky and Storm) + Clouds/Convection/Precip	**2028 and 2030**	2 Billion
Mass Change Grace-C (continuity)	**2028**	>500 million
Surface Bio and Geo (TIR and VSWIR)	**2027 and 2028**	900 million

Surface Deformation and Change. **NISAR launch 2024 (was 2021)** ; Five finalists down select **2025**

Four Explorer mission to Step 1; selection anticipated Q3 FY24 to eventual down seleted to 2 launched missions Launch 2929 and 2031

STV considerations for the next Decadal Survey (and our Midterm Review)

1. How will the pace (and continuance) of the Explorer mission launches impact arriving at an equivalence of an STV “Designated Observable (DO)”?

2. Cost: “flagship”?
   Is there a possibility that a successful STV DO could become a “continuity” mission? Can one mission meet the goals of your five self-defined STV fields?

3. The DS emphasized international partnerships to reduce DO mission costs. Are there *specific* collaborations/coordination with other space agencies that can be identified?

4. As always, and discussed in the STV 2021 report, what is anticipated to be useful capabilities in the commercial sector?

Could we get data like this for the planet (*please*)?